What is Variation?

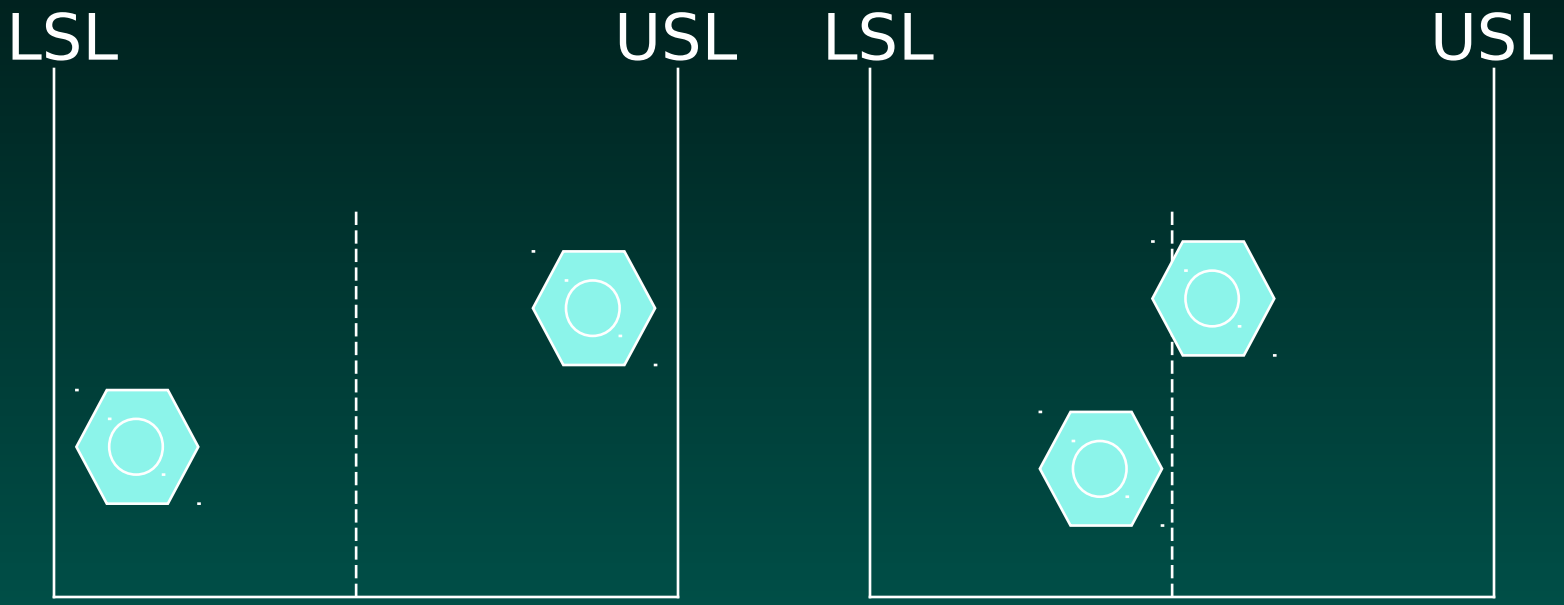
Less Variation

=

Higher Quality

What is Variation?

How the Loss Function Affects Product



Both are within spec
Which is more desirable?

Examining Variation

Definition

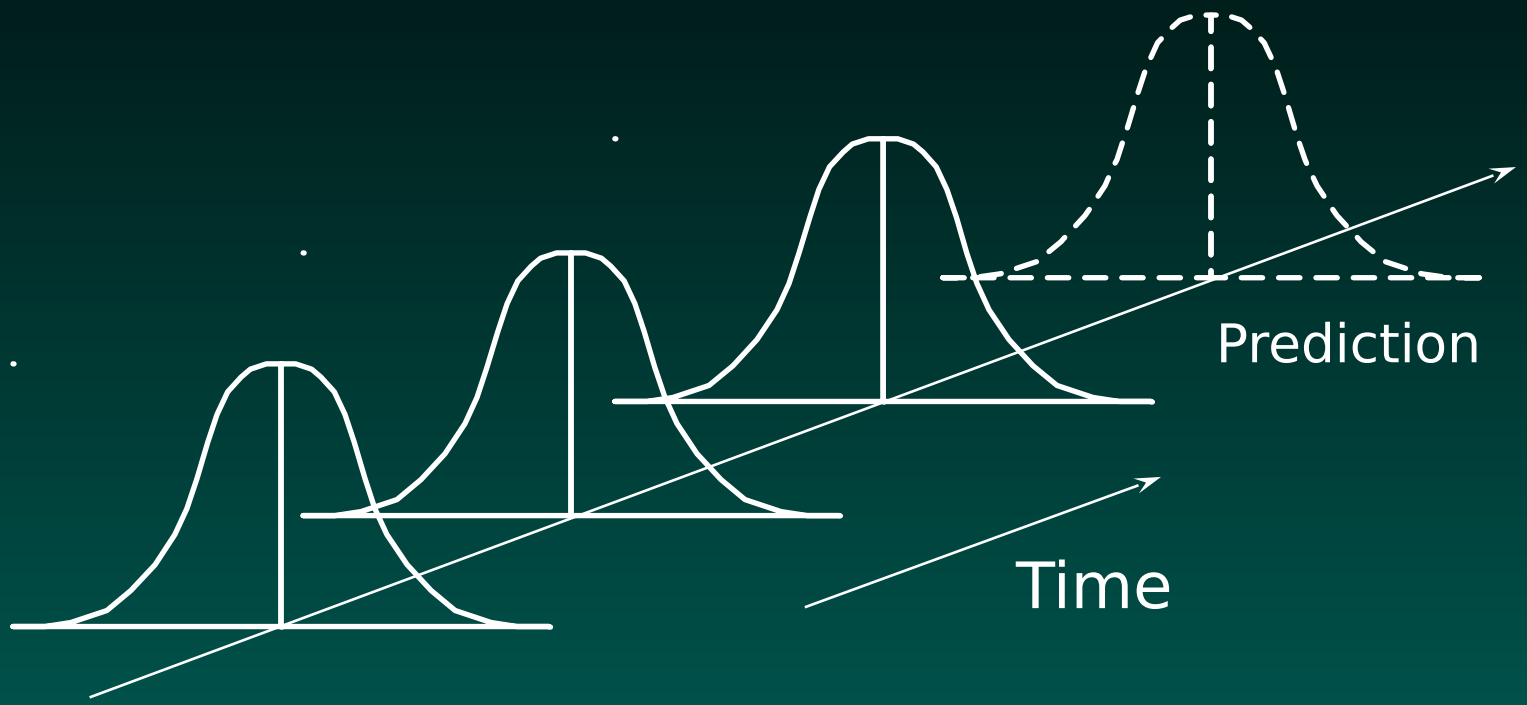
A **Stable Process** has the same normal distribution at all times.

A stable process is **In Control**

A stable process still has variation

Examining Variation

Stable Process



Normal distribution at all times

Examining Variation

Common Causes

The cause of variations in a stable process is called a **Common Cause**.

A common cause is a natural cause of variation in the system.

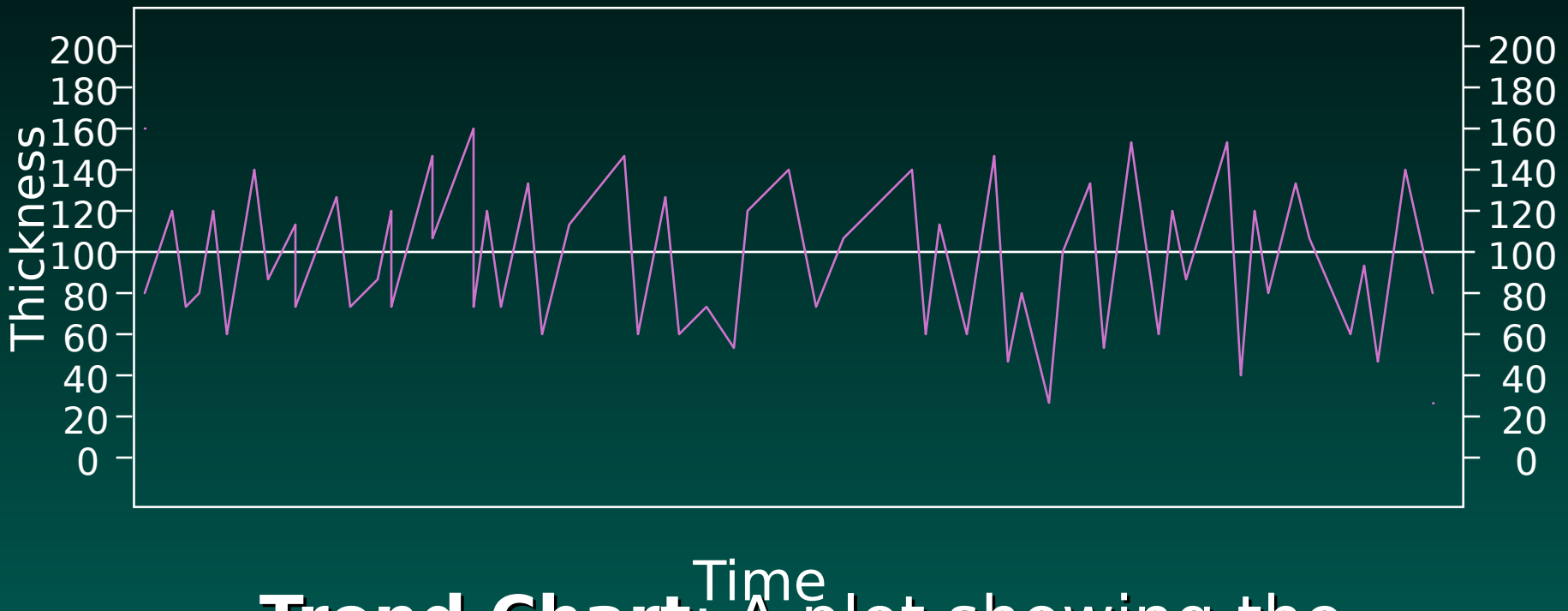
Examining Variation

Common Cause Examples

- Machine vibration
- Temperature fluctuations
- Slight variation in raw materials
- Human variation in setting control dials

Examining Variation

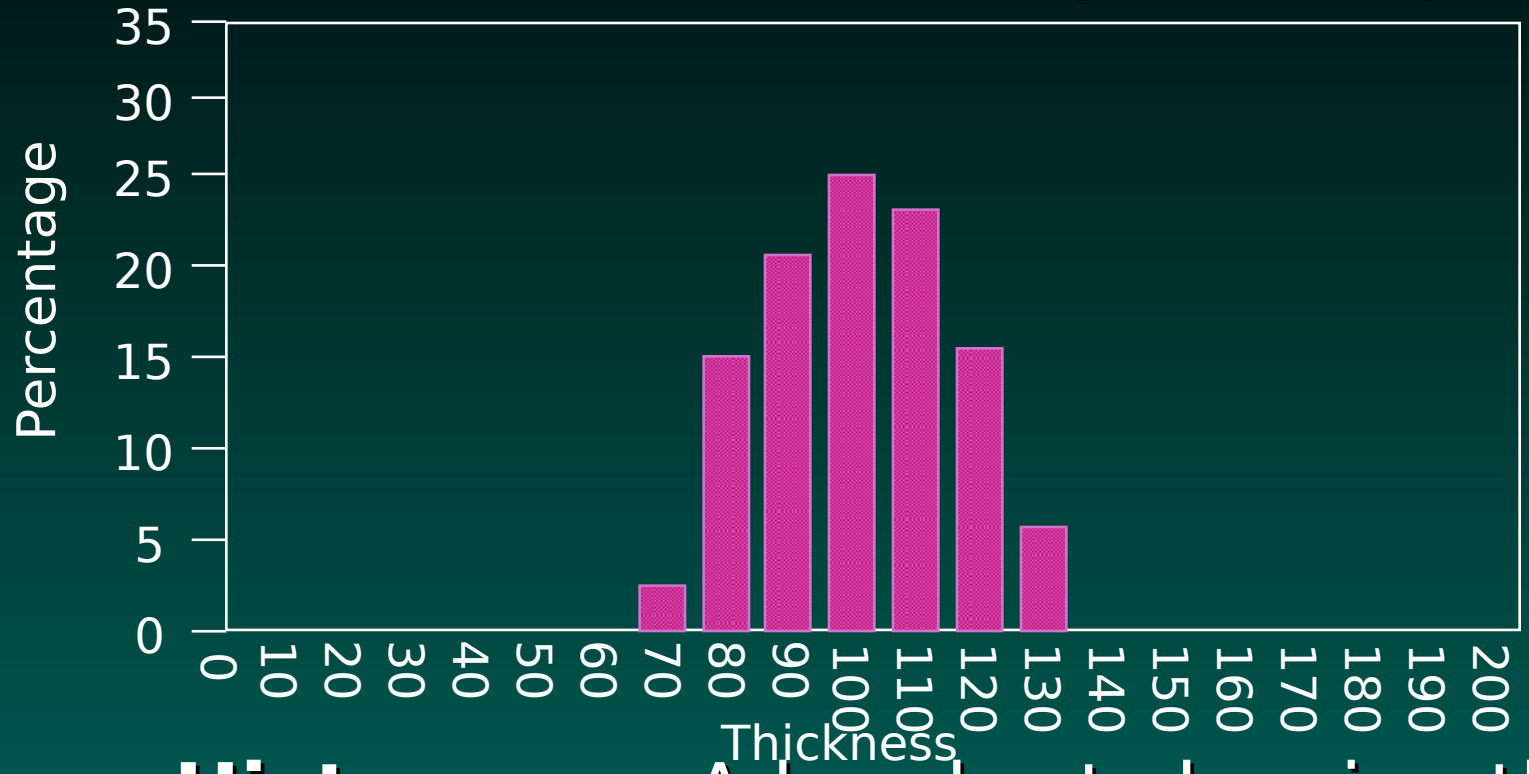
Tools for Examining Stability



Trend Chart: A plot showing the behavior of a process over time.

Examining Variation

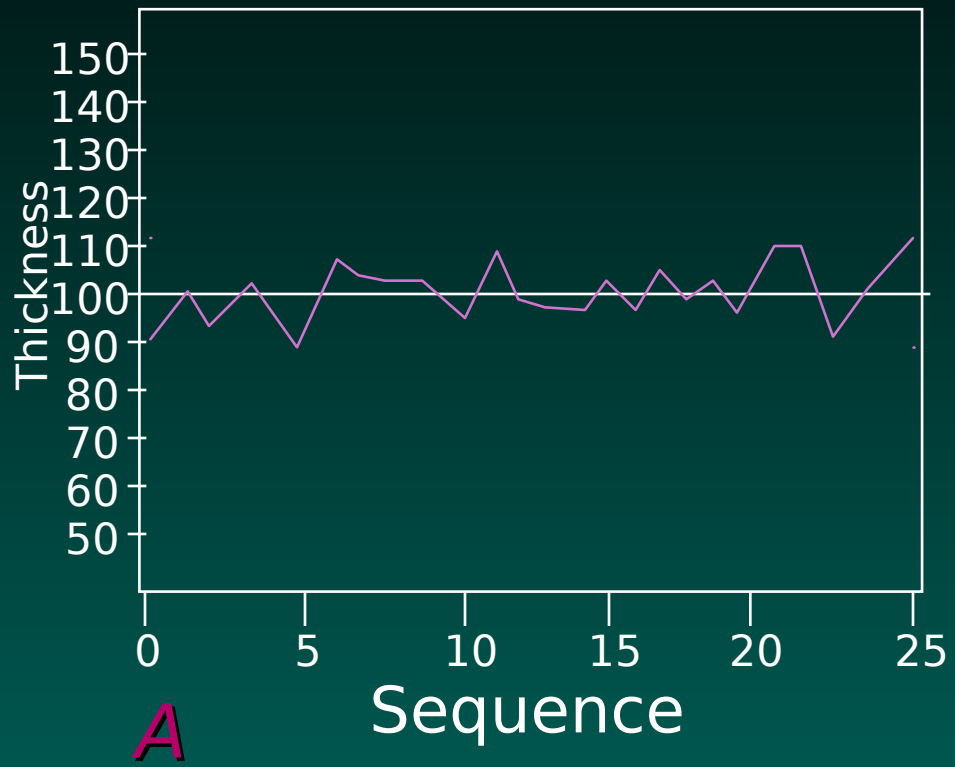
Tools for Examining Stability



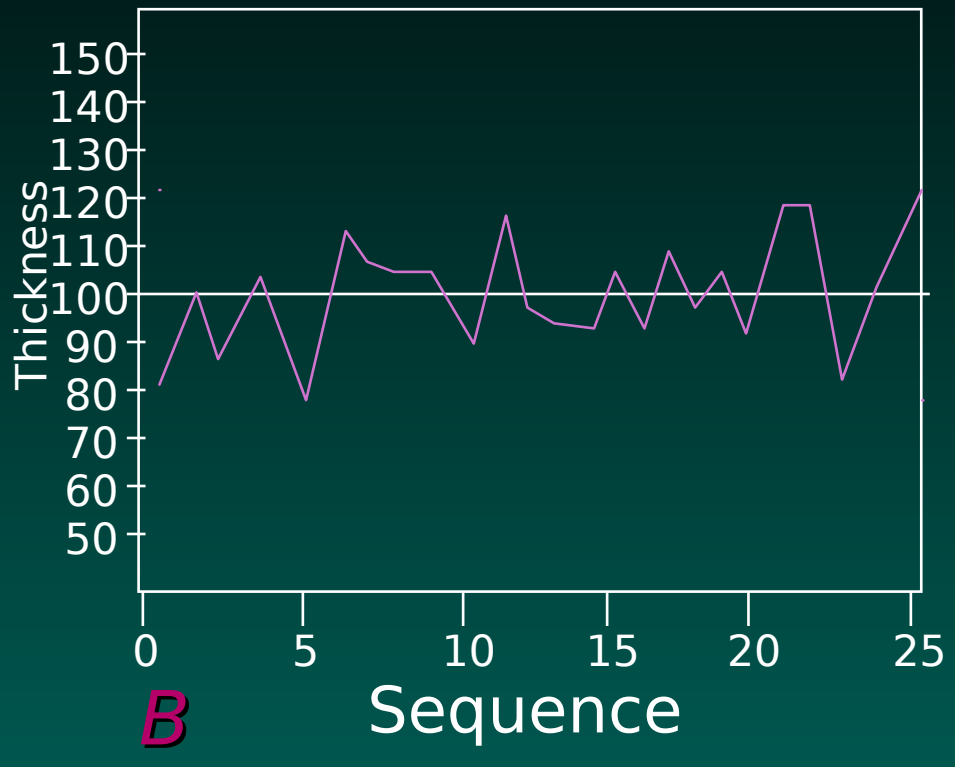
Histogram: A barchart showing the distribution of the process.

Examining Variation

Activity: Comparing stable processes



A

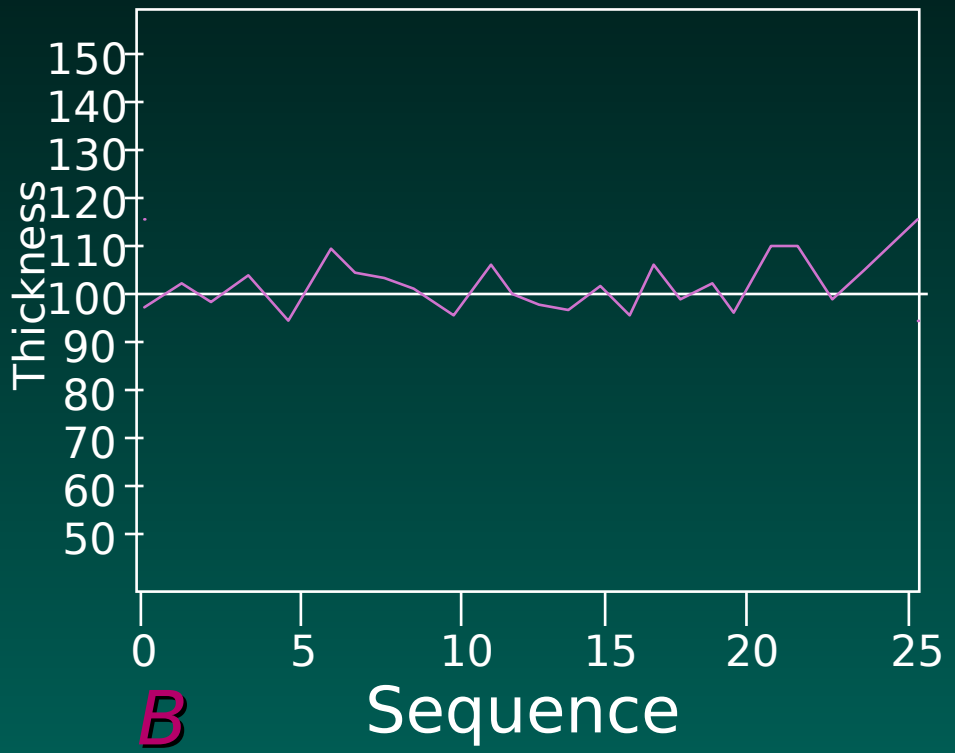


B

Which process has better quality?

Examining Variation

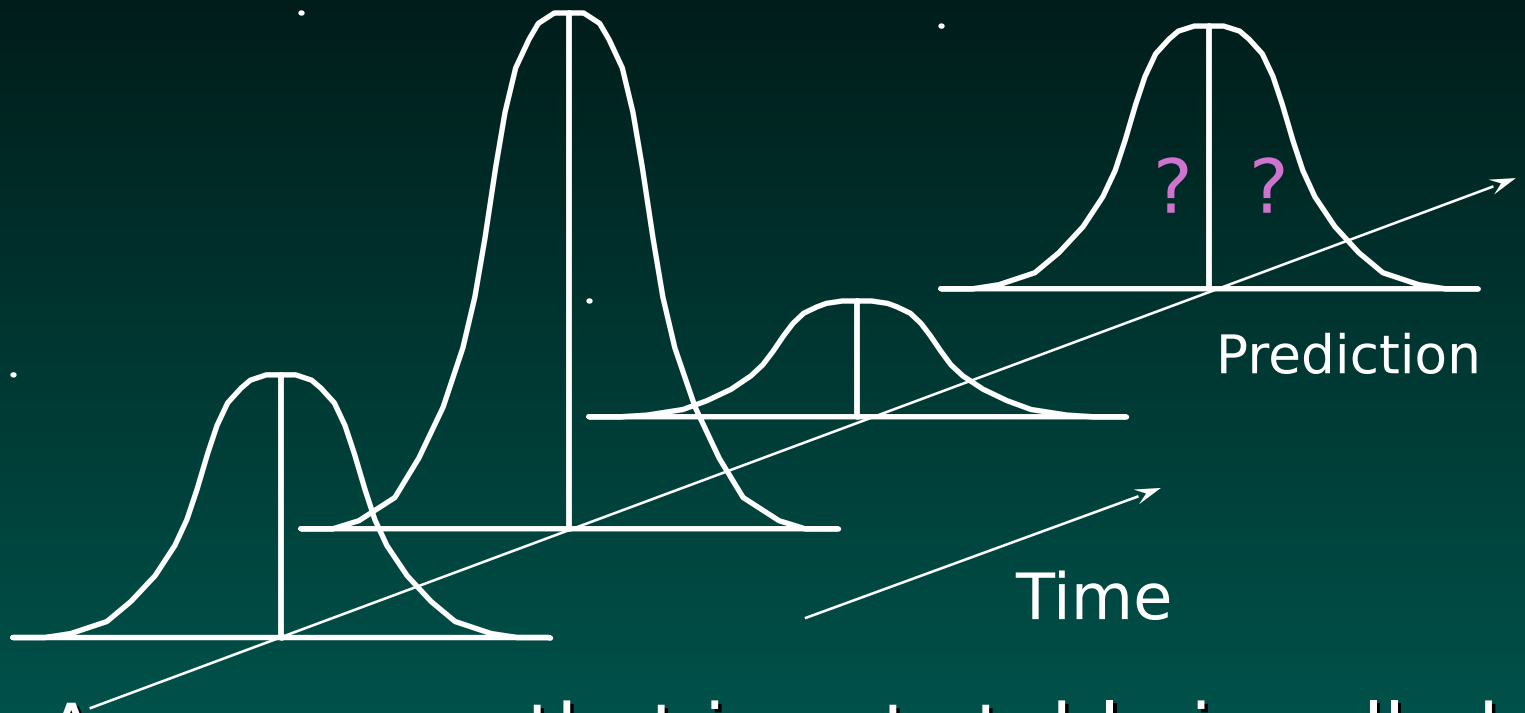
Activity: Comparing stable processes (cont'd)



Which process has better quality?

Examining Variation

Unstable Process



Any process that is not stable is called an **unstable** or **out-of-control** process.

Examining Variation

Kinds of Instability: Excursions

Examining Variation

Kinds of Instability: Shifts

Examining Variation

Kinds of Instability: Drifts

Examining Variation

Kinds of Instability: Cycles

Examining Variation

Kinds of Instability: Chaos

Examining Variation

Special Causes

Anything that causes variations that are not part of the stable process is called a **special cause**, **assignable cause**, or **unnatural cause**.

Examining Variation

Examples of Special Causes

- ✓ Batch of defective raw material
- ✓ Faulty set-up
- ✓ Human error
- ✓ Incorrect recipe
- ✓ Blown gasket
- ✓ Earthquake

Reducing Variation

Improving a Stable Process

Two strategies for improving a stable process

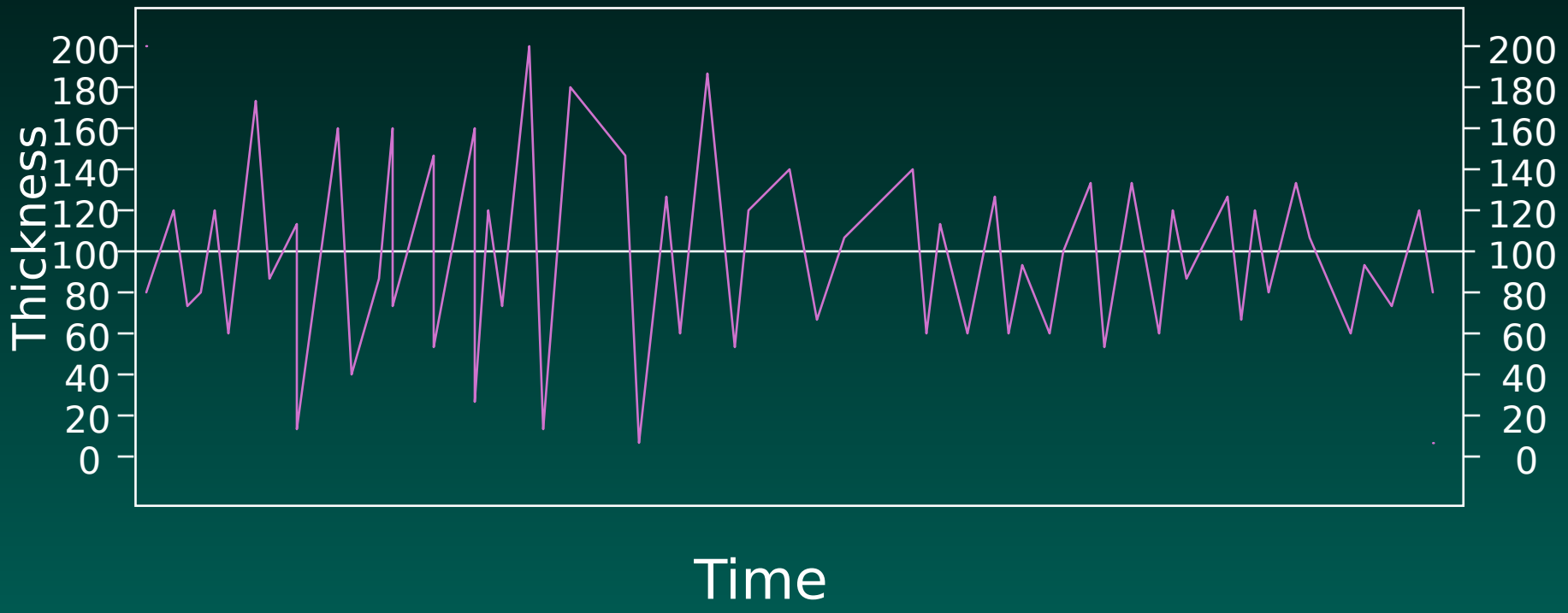
- ✓ Centering at Target
- ✓ Reducing Common Cause Variation

Reducing Variation

Centering at Target

Reducing Variation

Reducing Common Cause Variation



Reducing Variation

Reducing Variation in a Stable Process

Make Permanent Changes

Changes are based on the scientific approach

- ✓ Structured problem solving
- ✓ Planned experiments

Examples: new equipment, equipment upgrade, new procedure, new machine settings, better raw material

Reducing Variation

Reducing Variation in an Unstable Process

- ***Do not*** ignore special causes.
- ***Do*** quickly detect special cause variations.
- ***Do*** stop production until the process is fixed. (Reactive)
- ***Do*** identify and permanently eliminate special causes. (Preventive)

Reducing Variation

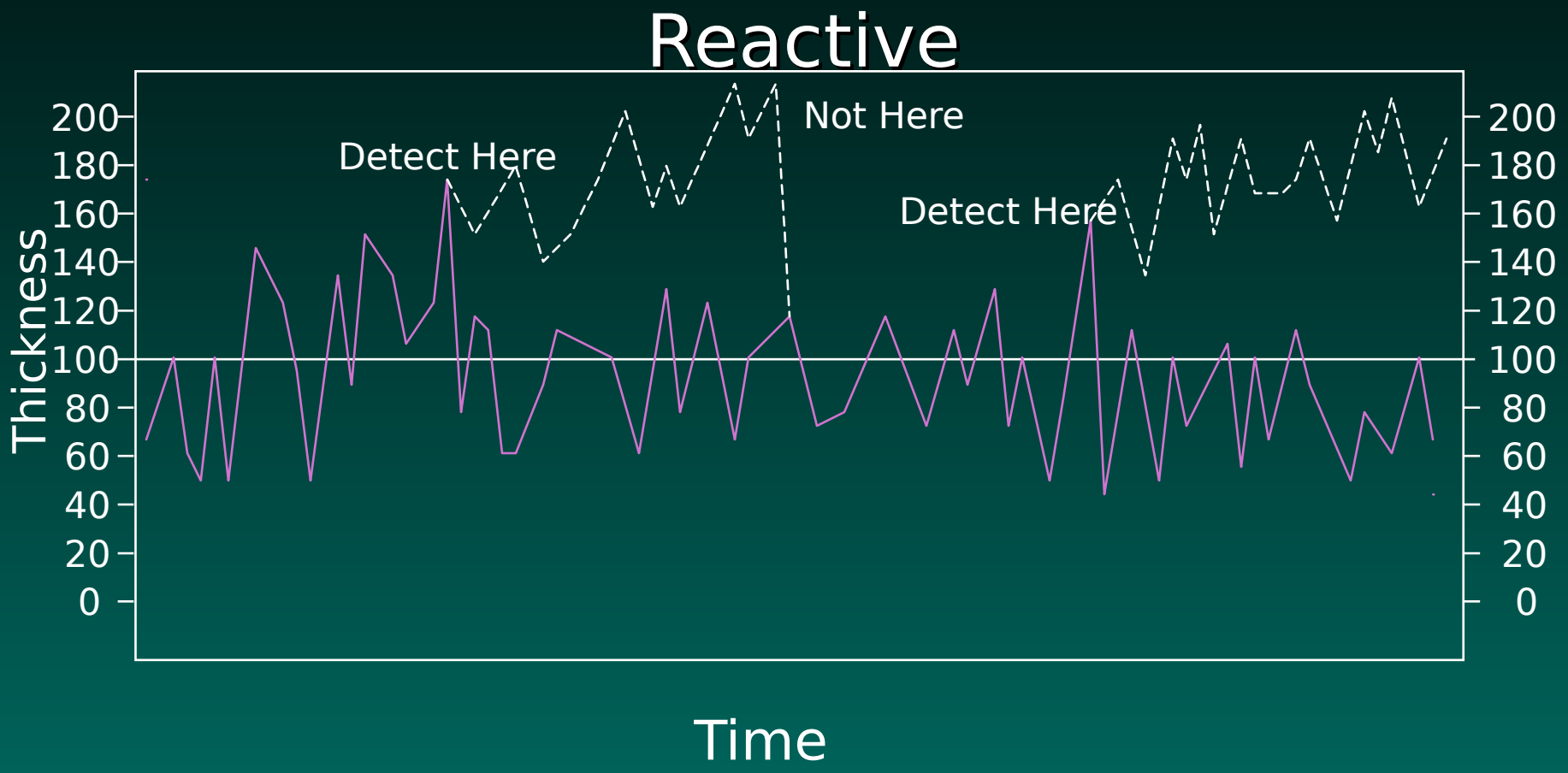
Improving an Unstable Process

Four Step Process

- ✓ Detect the special cause variation.
- ✓ Identify the special cause.
- ✓ Fix the process
  - Remove the special cause, or
  - Compensate for the special cause.
- ✓ Prevent the special cause from occurring again

Reducing Variation

Improving an Unstable Process

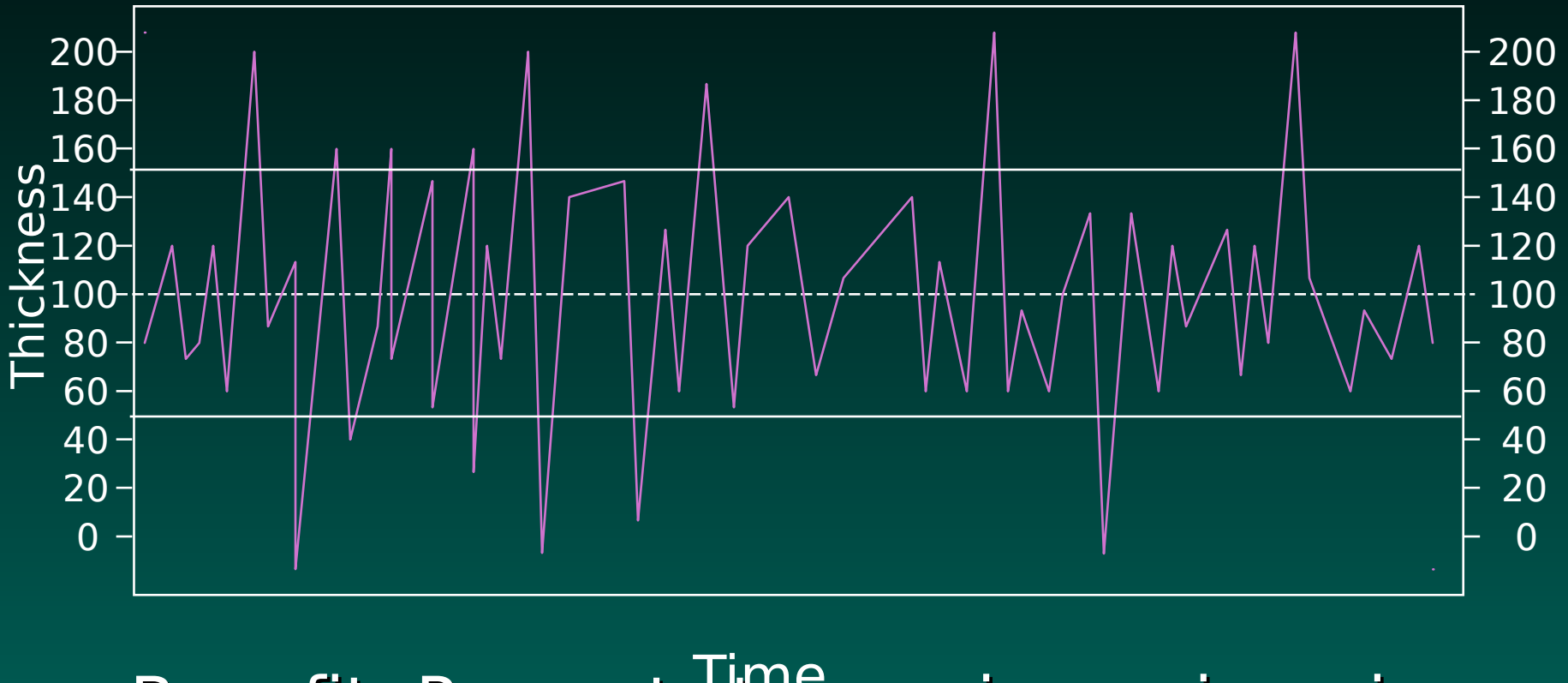


Detecting Variation

How can we decide if variation is the result of common or special cause?

Detecting Variation

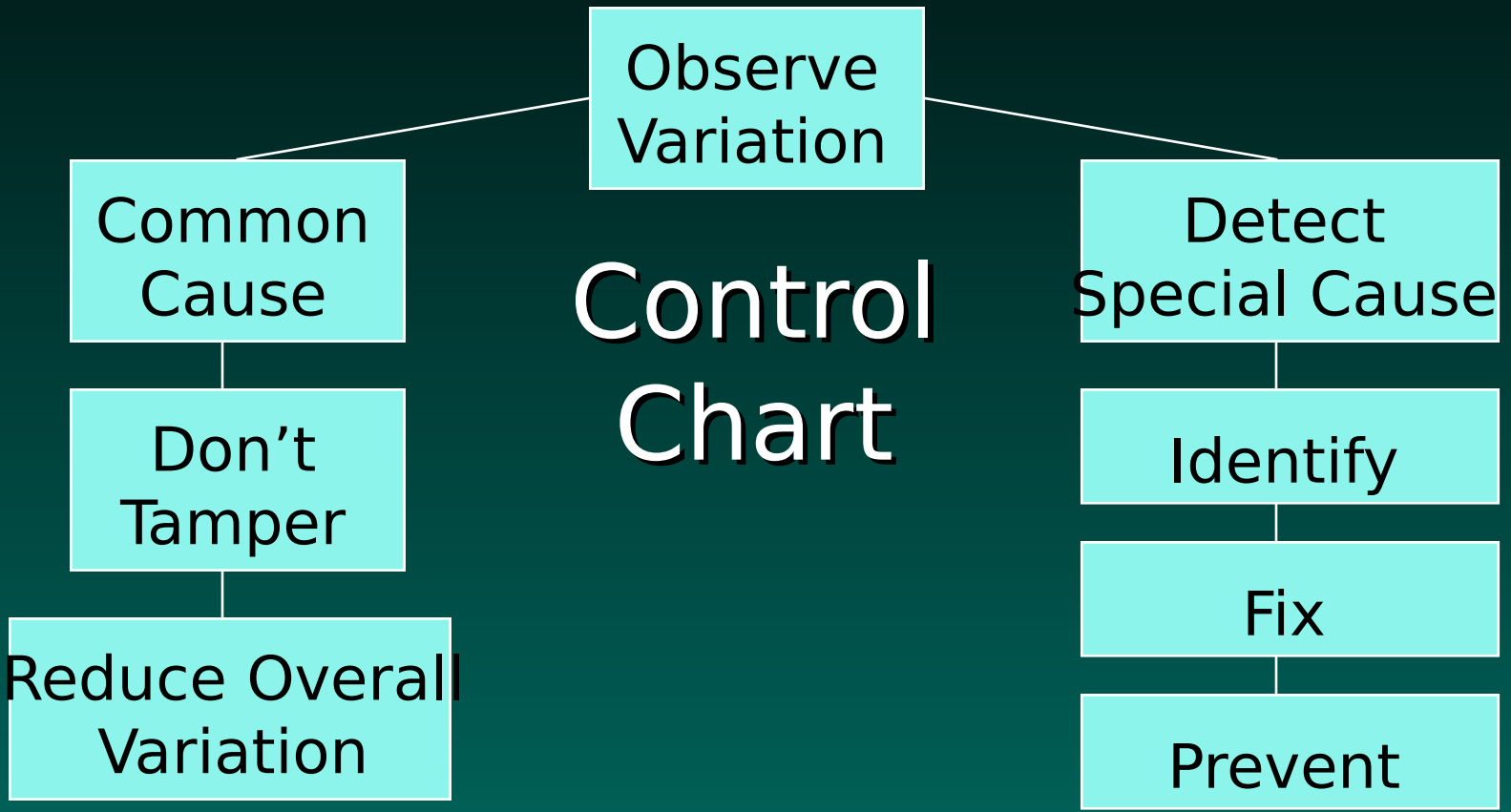
Tool: Control Chart



Benefit: Prevents tampering or ignoring

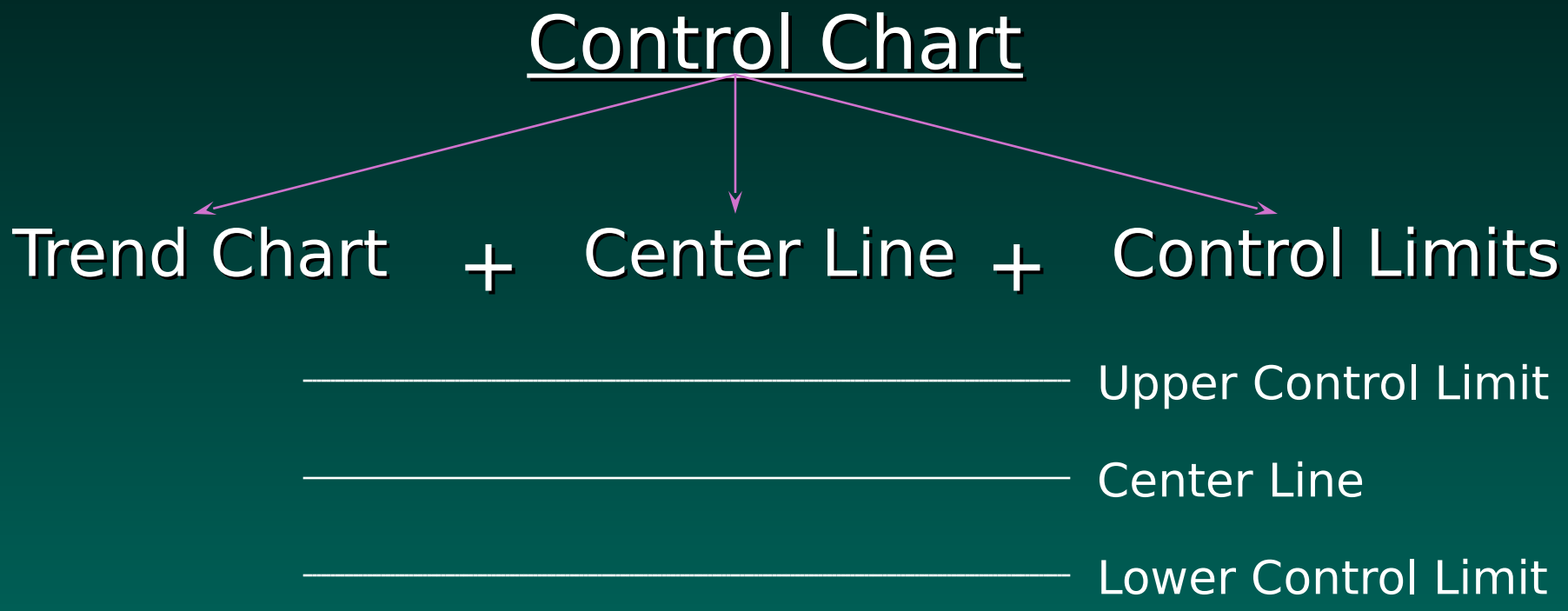
Detecting Variation

Control Chart for Detecting Variation



Detecting Variation

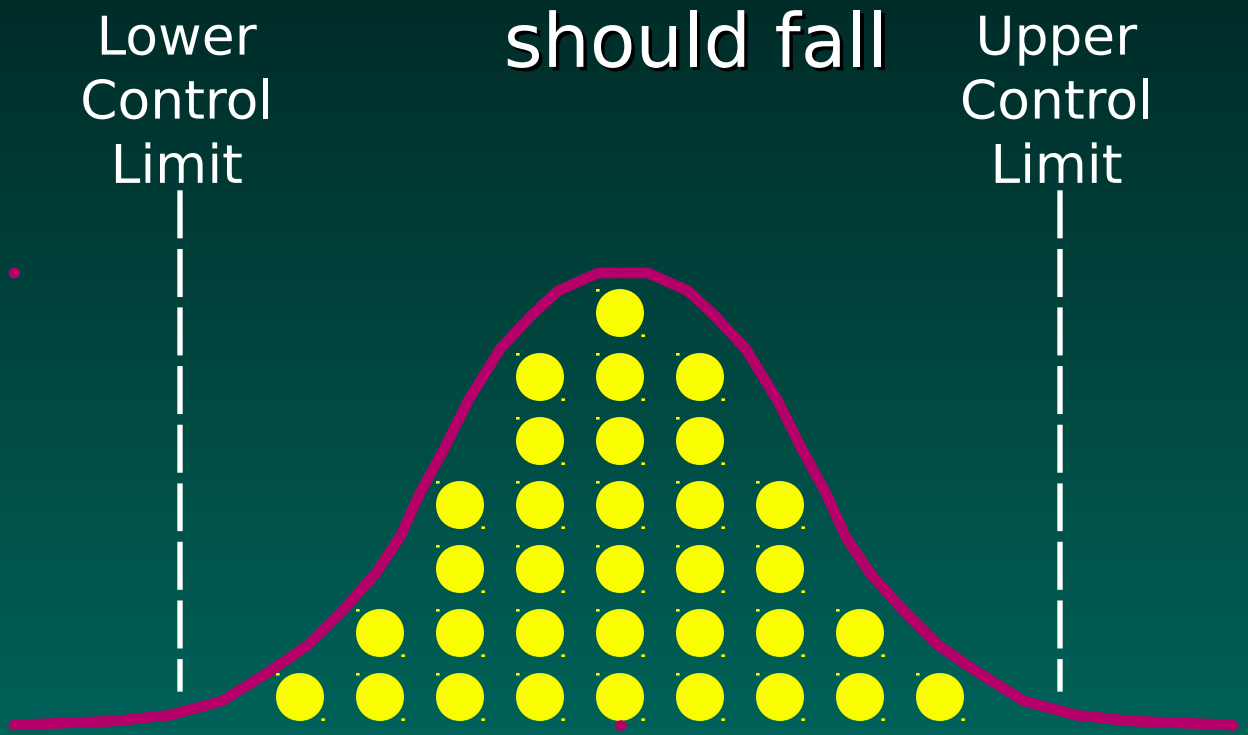
Control Chart for Detecting Variation



Detecting Variation

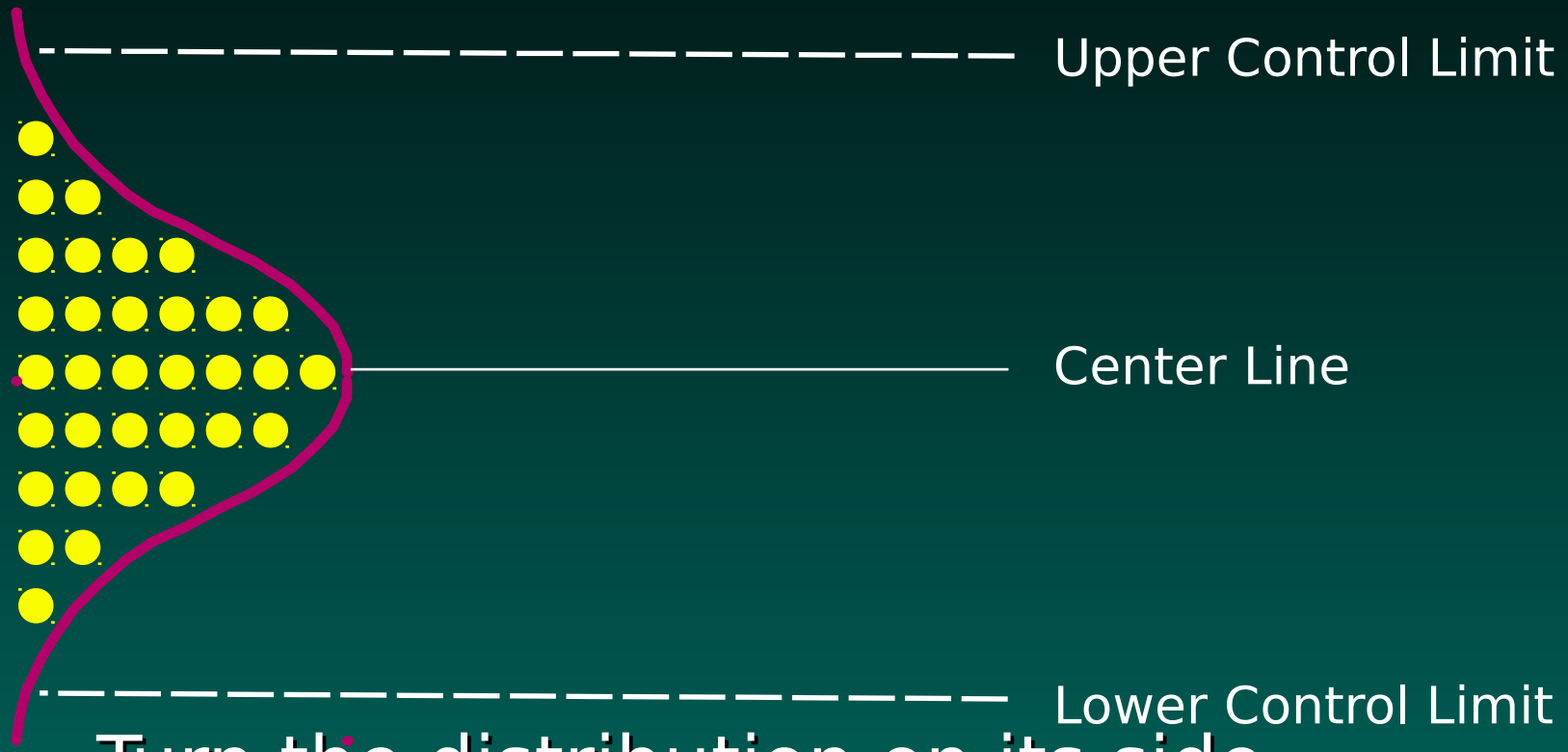
Control Limits

Control limits tell us where the measurements in a stable process should fall



Detecting Variation

Creating a Control Chart



Turn the distribution on its side

Detecting Variation

Creating a Control Chart

What is the Center Line?

Process mean, based on historical data

or

Process Target

Detecting Variation

Creating a Control Chart

Selecting the Center Line

Measurements: The center line should be the target, unless we are unable or unwilling to control the process to target.

Defects: Since the target is zero defects, the center line is the process mean.

Detecting Variation

Control Limits vs. Spec Limits

Control Limits	Spec Limits
✓ Based on performance of the *process*.	✓ Based on performance of the *product*.
✓ Tell us when to take action on the *process*.	✓ Tell us when to disposition the *product*.

Detecting Variation

Control Limits vs. Spec Limits

Focus On

Control Limits

Improve Process Quality

Improve Product Quality

Measurement Capability

Have you ever been bitten
by a measurement system?

black box

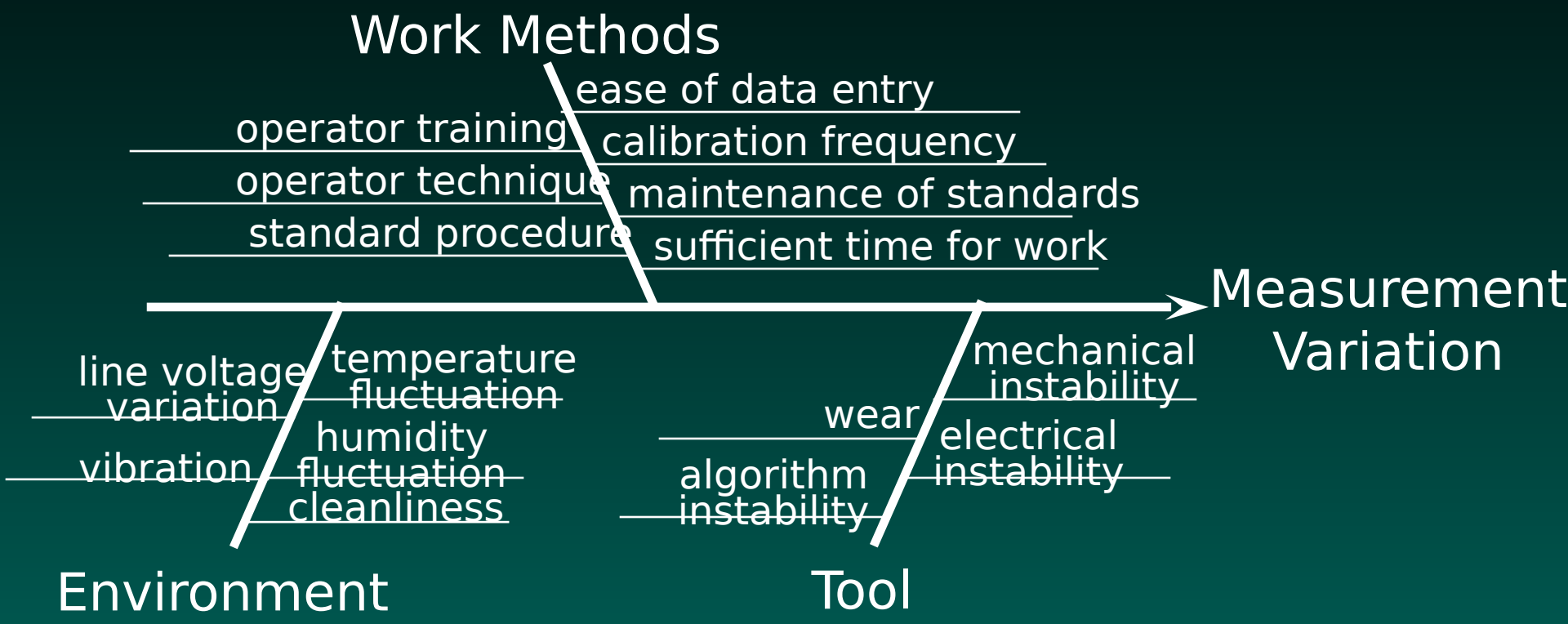
Measurement Capability

A Measurement Process

- Measurement tools themselves
  - hardware
  - software
- All the procedures for using the tools
  - which operators
  - set-up/handling procedures
  - off-line calculations and data entry
  - calibration frequency and technique

Measurement Capability

Why Do Measurements Vary?



NOTE: Not all of these will necessarily be significant sources of variation for every measurement system.

Measurement Capability

Assumptions We Often Make

- ✓ Metrology tools are perfectly accurate
- ✓ No day-to-day variation in performance
- ✓ No operator-to-operator variation

Measurement Capability

MCA Tells Us:

- How big is the measurement error?
- What are the sources of measurement error?
- Is the tool stable over time?
- Is the tool capable of making the measurements for this project?
- Is the tool capable of making the measurements for this process?
- What needs to be done to improve the measurement process?

Measurement Capability

Capability vs. Calibration

Calibration

Procedure to compare readings from a tool with a standard and then correct for any deviations.

Statistically: centering the mean of the distribution of readings on the “true value” (obtained from a standard).

Measurement Capability

Capability vs. Calibration (cont'd)

Capability

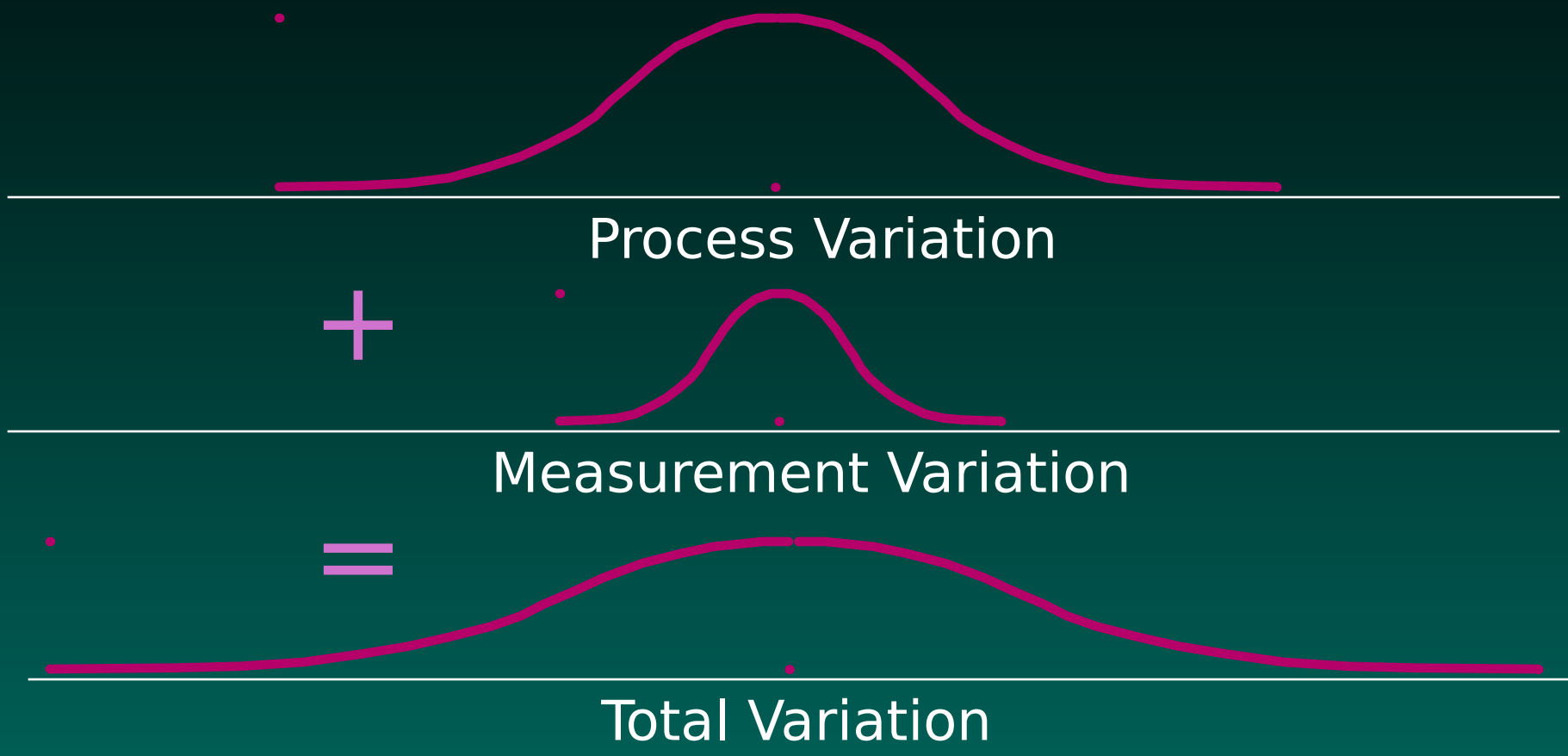
Procedure to identify and quantify sources of variation in readings and then eliminate them.

Statistically: fitting the model to the readings so that the components of variance can be estimated.

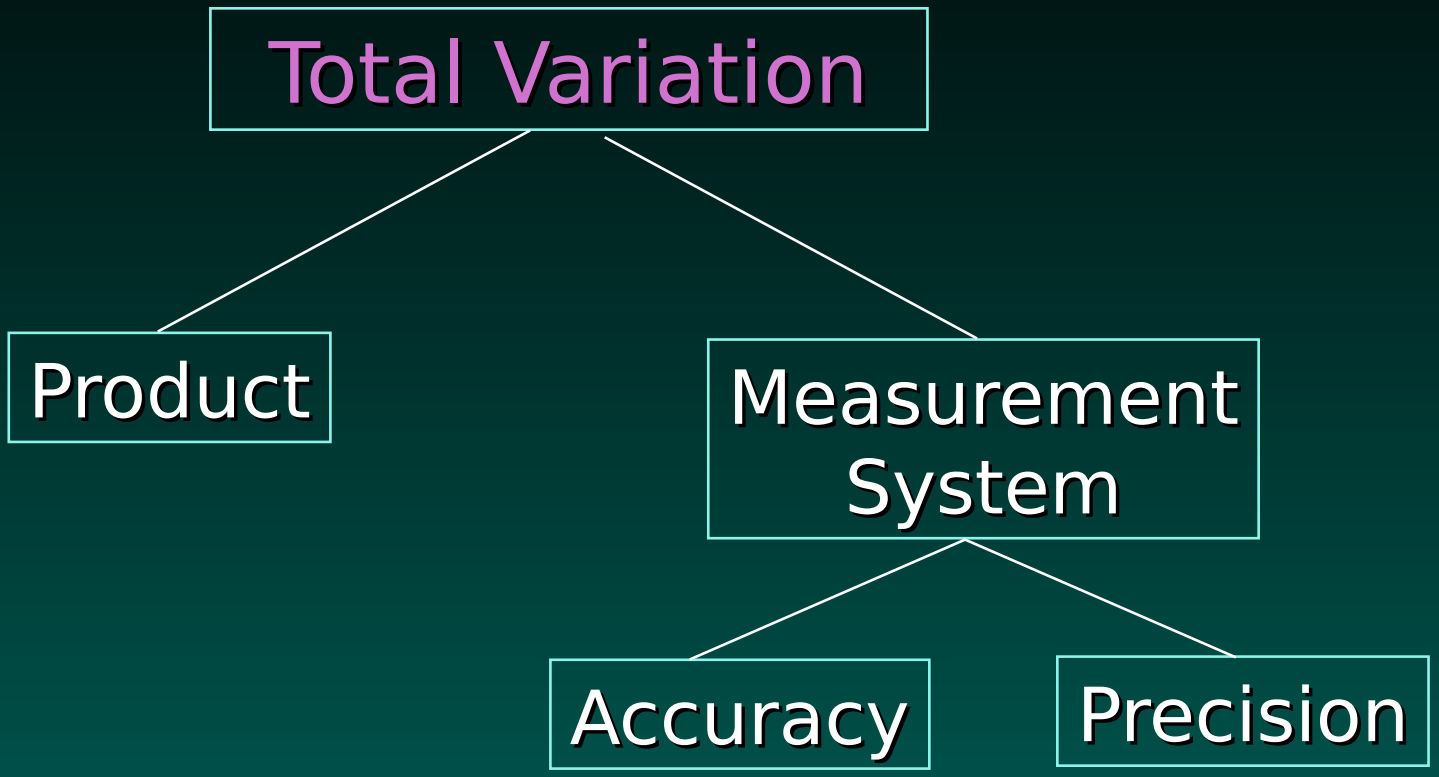
Both work together to keep measurement tool performing optimally.

Concepts and Vocabulary

Sources Of Variation



Introduction



Concepts and Vocabulary

Accuracy

The degree to which a process mean is on target

Related Terms

True Value

Bias

Concepts and Vocabulary

Precision

The degree of variability in a process

Related Terms

Repeatability

Reproducibility

Concepts and Vocabulary

Bias

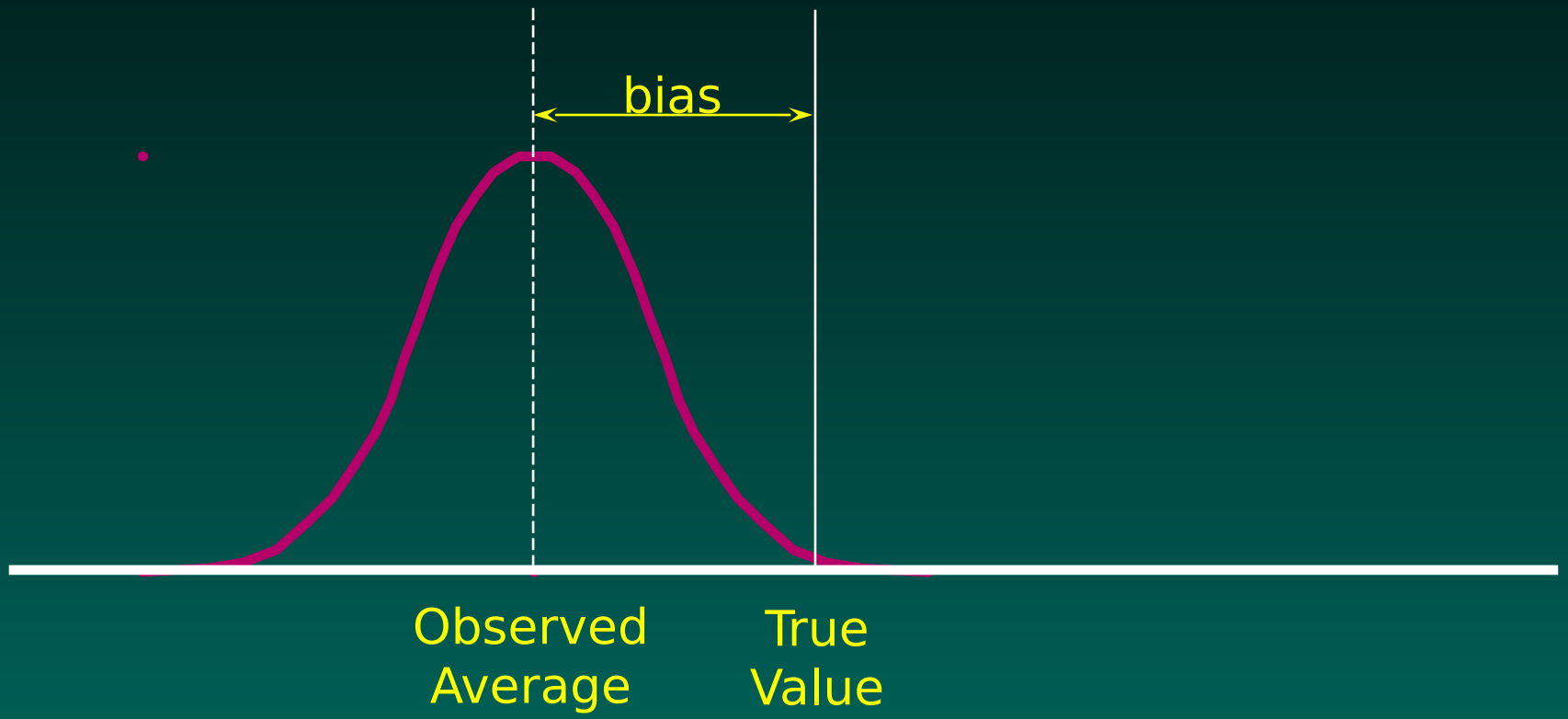
Distance between the average value of all the measurements and the **true value**. Can be positive or negative.

Bias = μ - True Value

- ✓ Measures the amount by which a tool is consistently off target from the truth.
- ✓ Bias is the numerical value we use to measure accuracy.
- ✓ Synonyms: systematic error, offset.

Concepts and Vocabulary

Bias



Concepts and Vocabulary

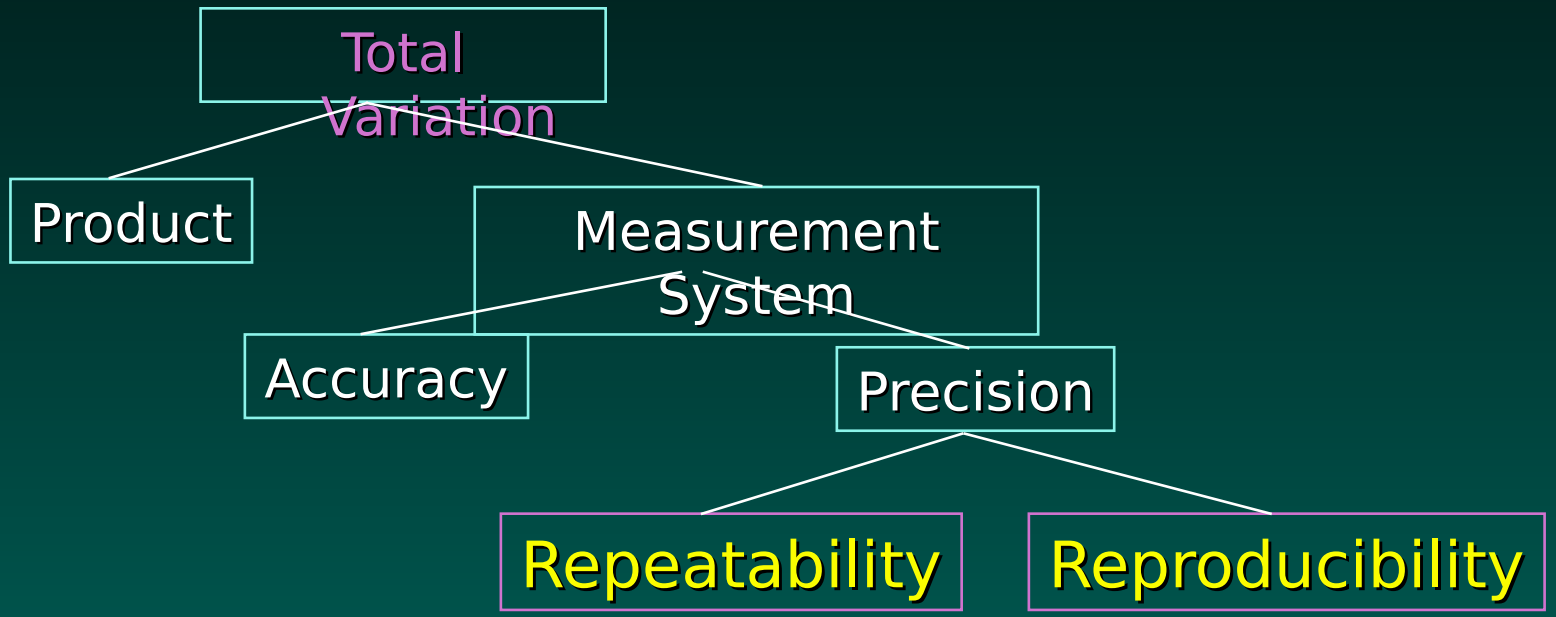
Precision Says Nothing About How Close The Measurements Are To The Truth.

Accuracy Says Nothing About How Close Measurements Are To Each Other.

Concepts and Vocabulary

Precision

Can be separated into repeatability and reproducibility



These characteristics have the relationship:

$$\sigma^2_{ms} = \sigma^2_{rpt} + \sigma^2_{rpd}$$

Concepts and Vocabulary

Repeatability

Variation that results when repeated measurements are made of the same parameter under absolutely identical conditions.

- ✓Same operator
- ✓Same set-up procedure
- ✓Same part
- ✓Same environmental conditions

Repeatability (σ^2_{rpt}) is usually much smaller (better) than the precision of the system.

Concepts and Vocabulary

Reproducibility

The variation that results when different conditions are used to make the measurement.

- ✓Different Operators
- ✓Different Set-Up Procedures
- ✓Different Measurement Tools
- ✓Different Environmental Conditions
- ✓Different Days

Reproducibility (σ_{rpd}), is approximately the standard deviation of the averages of measurements from different measurement conditions.